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Literature Review on Protozoa Infection (Genus Giardia Lamblia): Threat to Swimming Athlete's hygiene

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ABSTRACTS
Freshwater sports can expose participants to a variety of pathogens, including **Giardia lamblia**, which can cause significant health risks. Swimming athletes, who often train in public pools or open water, have a high risk of exposure to these parasites due to direct contact with water that may be contaminated. **Purpose:** presents a comprehensive literature review on Giardia lamblia infection in the human body and identify the risk, impact and recommendations for infection prevention for swimming athletes. **Materials and Methods:** We searched Google Scholar, PubMed, and Scopus using the keywords: '*Giardia duodenalis* OR *Giardia lamblia* OR *Giardia intestinalis* OR intestinal protozoa OR giardiasis OR giardiasis in swimming athletes. **Result:** . Giardia Lamblia is the only intestinal flagellate pathogenic protozoan known to be a major cause of the worldwide parasitic gastrointestinal disease called giardiasis (diarrhea) in vertebrates. Giardia infection can impact the health of athletes, especially those with weakened immune systems. Common symptoms include diarrhoea, abdominal cramps/pain, abdominal, bloating, nausea, and vomiting and dehydration. Research emphasises the importance of hygiene awareness and health education to prevent infections in swimming pools. **Conclusion:** In summary, enhancing hygiene awareness and health education is vital for preventing infections in swimming pools and freshwater sports. Key strategies include monitoring water quality, maintaining sanitation, and promoting hand washing. Increased awareness and regular health checks are essential, along with broader screening for giardiasis in at-risk populations.
Keywords: Giardia lamblia, Giardiasis, Freshwater sports, Swimming athletes

Background

Freshwater sports can expose participants to a variety of pathogens, including bacteria, viruses, parasites and fungi, which can cause significant health risks. (Delamare, Septfons, Alfandari, & Mailles, 2024). Swimming pools and recreational water are significant transmission routes of infection, with several outbreaks linked to fecal contamination in swimming pools (Krumrie, et al., 2022). Swimming pools in Brazil contaminated with pathogenic protozoa that can cause gastrointestinal infections (Pineda, et al., 2020). Despite the many health benefits of regular physical activity, it should not be overshadowed by the risk of infection (Delamare, Septfons, Alfandari, & Mailles, 2024).

The study was conducted in the Netherlands by taking water samples from seven swimming pool filters in five locations over the course of one year. Of the 153 samples analyzed, 18 (11.8%) were found to be mostly positive for Giardia (5.9%) (Schets, Engels, & Evers, 2004). Giardia cysts were the most common oocysts detected at 19% in swimming pools in Brazil (Pineda, et al., 2020). Research shows that swimming pools can be a source of Giardia infection, which can be a health risk for pool users (Pineda, et al., 2020), especially for individuals with weakened immune systems (Schets, Engels, & Evers, 2004). Awareness and preventive measures are essential to ensure the safety of pool users (Delamare, Septfons, Alfandari, & Mailles, 2024). Giardia Lamblia is the only intestinal

flagellate pathogenic protozoan known to be a major cause of the worldwide parasitic gastrointestinal disease called giardiasis (diarrhea) in vertebrates (Krumrie, et al., 2022) (Dunn & Juergens., 2024). Symptoms of giardiasis include diarrhea, abdominal pain, bloating, nausea, and vomiting (CDC, 2024).

Disease transmission can be through fecal-oral transmission of the environmentally resistant cyst stage transmitted through the feces of one host and ingested with food/water by another (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). The risk of infection is strongly influenced by geographical and environmental factors, so it is important to understand these risk factors for infection (Delamare, Septfons, Alfandari, & Mailles, 2024). Significant risk factors included maternal hand washing habits before feeding, drinking water source, domestic water storage, and recent travel history (Ali, Parkash, Mangrio, & Shaikh, 2025). Infection has also been associated with recreational water use, including swimming pools, lakes and water theme parks. Conventional water treatment procedures (filtration and chlorination) are not fully effective against Giardia cysts as they are quite small and potent (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Understanding the infection risks associated with outdoor sports activities should not be overlooked despite the enormous health benefits of such sports for the human body (Velay, et al., 2024).

Swimming athletes, who often train in public pools or open water, have a high risk of exposure to these parasites due to direct contact with water that may be contaminated. The association of infectious diseases and types of freshwater sports has been widely reported in various countries (Delamare, Septfons, Alfandari, & Mailles, 2024). In England, an AGI outbreak associated with Giardia contamination was reported after a swimming competition on the River Thames in London. The reported attack rate was 53%. Heavy rainfall prior to the incident is suspected to be a risk factor for giardiasis infection (Delamare, Septfons, Alfandari, & Mailles, 2024). The journal noted the prevalence of Giardia infection among young swimmers, with 54% of intestinal parasite infections detected, including Giardia lamblia (Hassanein, Masoud, Awwad, Abdel-Salam, & Shehata, 2023). Giardia infection can impact the health of athletes, especially those with weakened immune systems (Schets, Engels, & Evers, 2004). The main problem that is the focus of this study is the high prevalence of Giardia lamblia infection in swimming athletes and its impact on athlete health during competition or training, which requires serious attention from related parties.

Writing Objectives

1. Present a comprehensive literature review on Giardia lamblia infection in the human body.
2. Identify the risk, impact and recommendations for infection prevention for swimming athletes.

Giardia lamblia: Characteristics and Epidemiology

1. Description of the Giardia Genus

Giardia lamblia was first observed by Antony von Leewenhoek (1681) when examining his own feces and Lambi (1859) described this parasite and named it Giardia lamblia (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Giardia Lamblia (also called: Giardia duodenalis or Giardia intestinalis), the only intestinal flagellate species that causes endemic and epidemic giardiasis (diarrhea) in humans (Dunn & Juergens, 2024; Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Giardiasis is a common small intestine infection characterized by symptoms such as watery diarrhea and abdominal bloating (Dunn & Juergens, 2024). There are 7 distinct genetic assemblies (A to F), but only genotypes A and B have been found to infect humans (Dunn & Juergens, 2024). G. duodenalis is identified in three types of assemblages in the human body: A, B, and E (Zhao, et al., 2025).

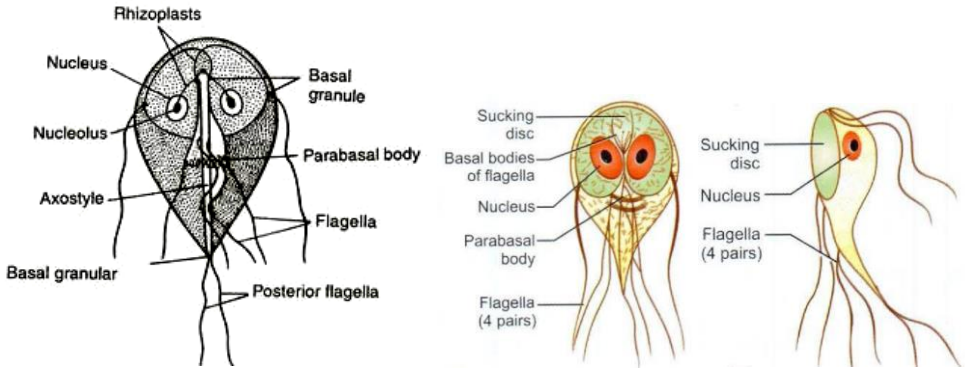


Figure 1. Morphology of Giardia lamblia trophozoites (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019).

Giardia lamblia trophozoites are the active feeding phase of the parasite, measuring 9-21 µm long and 5-15 µm wide, responsible for colonization in the intestine. The shape of the trophozoite is pear-shaped or tennis racket-shaped with a rounded anterior end and a tapered posterior end. The dorsal surface is convex while the ventral surface is concave with a suction disc (adhesive disc) that serves as an organ for attachment. Behind the adhesive disc is a pair of large curved and transverse median bodies, which are unique. The body is bilaterally symmetrical and all organs are paired. Giardia lamblia trophozoites have two median bodies, two axostils, two nuclei and four pairs of flagella. Each nucleus consists of a large central karyosome that gives the parasite its characteristic appearance on stained preparations. The cytoplasm is uniform and fine-grained. Motility shows typical "falling leaf type" motility. (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019)

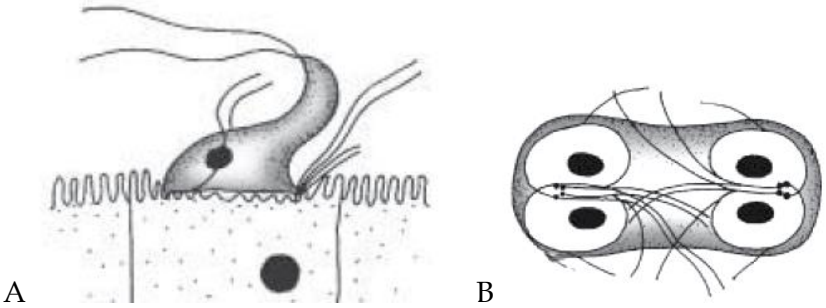
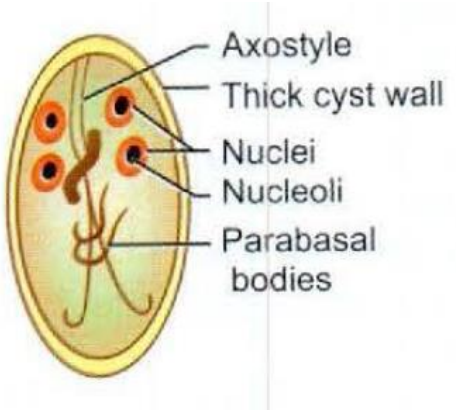


Figure 2. Scale is 10 µm (A) Trophozoite with adhesive disk attached to the edge of intestinal epithelial cell microvilli. (B) Trophozoite, during division (Lucius, et al., 2017).

Giardia lamblia cysts are the infective stage of the parasite. The mature cyst is oval or ellipsoid in shape and measures 8-12 µm long and 7-10 µm wide. The cyst is surrounded by a thick cyst wall. The cytoplasm is grainy and separated from the cyst wall by a clear space. The axostyle is located more or less diagonally. The cyst contains 4 nuclei. Remnants of flagella and the periphery of the suction disc can be seen in the cytoplasm (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019).



i.

Figure 3. Morphology of four-nucleated (quadrinucleated) Giardia lamblia cysts (Ghosh, 2018).

2. Epidemiology of Giardia Infection

Giardiasis is the most common enteric protozoan infection worldwide. Giardiasis is distributed in temperate and tropical regions, with prevalence rates between 4% and 42% (Dunn & Juergens, 2024). Geographical Distribution Giardia lamblia is present worldwide, more commonly in children (CDC, 2024). Affects nearly 2% of adults and 8% of children in developed countries (Dunn & Juergens, 2024). Giardia infections are more common in children aged 5-14 years, with a higher proportion of Giardia lamblia infections compared with Cryptosporidium (Lafarga-Molina, et al., 2025).

Giardia infection is very common in developing countries, with prevalence varying from 15% to 50% (Barasa, Indusa, & Were, 2025). Giardiasis is more common in low- to middle-income countries (20-30%) compared to high-income countries (2-7%) (Krumrie, et al., 2022). G. lamblia infection is a significant health problem especially in areas with limited access to clean water and good sanitation (El-Zohri, Alsaadawy, Aladawy, & Shatat, 2025).

Of the 21,172 reported cases of giardiasis, 32% were travel-related cases (Hommes, Dörre, Behnke, Stark, & Faber, 2023). In the United States, at-risk populations include international travellers, outdoor enthusiasts, childcare workers, men who have sex with men, and professionals who come into contact with human waste (Dunn & Juergens., 2024). Giardiasis shows a peak incidence during late summer and early autumn, correlating with increased outdoor water activity (Dunn & Juergens, 2024).

Research shows that swimming pools can be a source of Giardia infection, especially among children who are more susceptible. Prevalence of Giardia infection among young swimmers, with 54% of intestinal parasite infections detected, including Giardia lamblia (Hassanein, Masoud, Awwad, Abdel-Salam, & Shehata, 2023).

The infection has also been associated with recreational use of water, including swimming pools, lakes and water theme parks. Conventional water treatment procedures (filtration and chlorination) are not fully effective against Giardia cysts as they are quite small and hardy. (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019).

Trophozoites have been observed to swim with a distinct corkscrew motion in the luminal content as well as adhere to the intestinal mucosal surface with their ventral adhesive disc (when detached, they leave a distinct oval impression on the microvilli layer) (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). A cross-sectional study of 528 swimmers was examined. The prevalence of intestinal parasite infection was 54%, with Giardia lamblia as one of the detected pathogens (Hassanein, Masoud, Awwad, Abdel-Salam, & Shehata, 2023).

3. Mode of transmission

Cysts are the resistant form and are responsible for the transmission of giardiasis, both cysts and trophozoites can be found in the feces (diagnostic stage). These cysts are hardy and can survive for several months in cold water (CDC, 2024). Fecal-oral transmission (hands or fomites) of the environmentally resistant cyst stage transmitted through the feces of one host and ingested with contaminated food/water by another host (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019) (CDC, 2024). Most infections are transmitted accidentally through "hand-to-mouth" contact where objects contaminated by feces are put into the mouth (e.g. contaminated fingers, eating utensils, clothing, etc.) (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019).

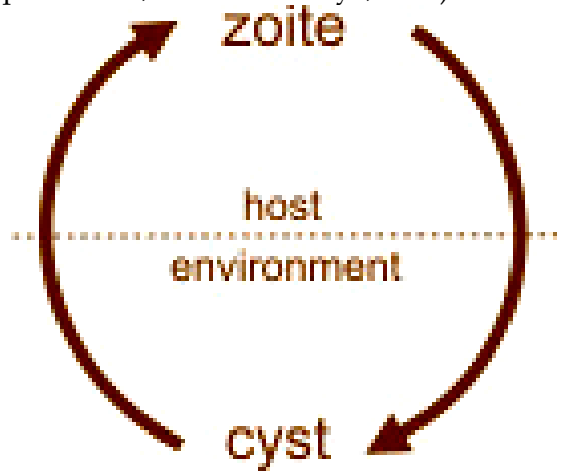


Figure 4. Fecal-oral mode of transmission (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019).

Infections are transmitted between hosts through fecal-oral transmission of the encysted stage of the parasite. When trophozoites pass through the colon, they form unflagellated cysts that are excreted and contaminate the environment. Cysts are said to be reproductive as they undergo nuclear division as they mature into quadrinucleate (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). An infected person can shed 1 million to 1 billion cysts every day, while the infectious dose can be up to 10. People with subclinical disease can act as carriers, potentially infecting others (Dunn & Juergens., 2024). These cysts are quite resistant to external environmental conditions and can survive for some time, especially in cool moist conditions.

The cysts also contaminate water supplies and cause infection when subsequently ingested with drinking water or consumption of foodstuffs diluted or washed with contaminated water (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Giardiasis in high-income countries is often overlooked and is more common through local routes such as water contamination rather than simply through international travel (Krumrie, et al., 2022).

4. Life cycle of Giardia lamblia

The life cycle of G. lamblia is simple and completed in only one definitive host, humans. No intermediate host is required. Infection is acquired orally through ingestion of cysts from hands or contaminated water or food (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Excystation occurs in the stomach and in the duodenum in the presence of gastric acid and pancreatic enzymes (chymotrypsin and tryptophan). Excystation stimuli include various post-gastric digestive conditions (bile salts, enzymes, pH, microaerophilic conditions, etc). An acidic environment with a pH of 1.3-2.7 is required for excretion (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Excystation releases two trophozoites (each cyst produces two trophozoites) duodenum

within 30 minutes after ingestion (CDC, 2024). These trophozoites proliferate in the small intestine through longitudinal binary division, and remain in the lumen of the proximal small intestine where they can either be free or attached to the mucosa by ventral sucking discs (CDC, 2024; Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Then the trophozoites attach to the enterocytes through ventral suckers mediated probably through mannose-binding lectin present on the surface of the trophozoites (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019).

Giardia lamblia disrupts small intestinal epithelial cell junctions and brush border enzymes so that infected patients show altered gastrointestinal motility. This protozoan releases thiol proteinases and lectins that have cytopathic effects. The combination of these effects increases permeability and impairs saccharide absorption (Dunn & Juergens, 2024).

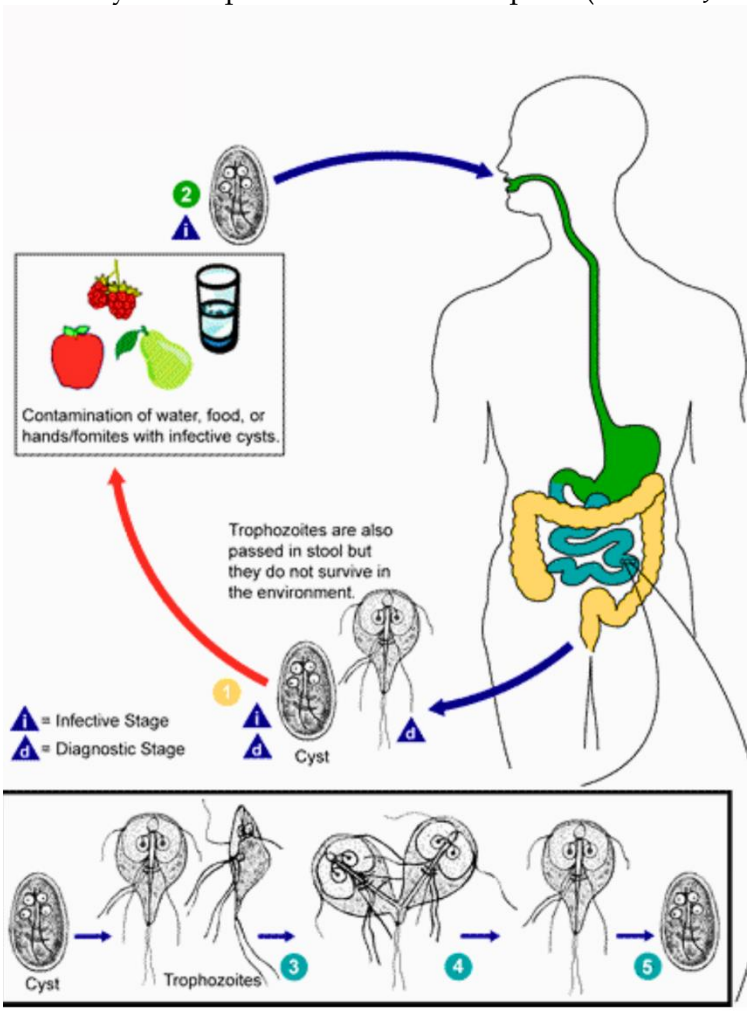


Figure 5. Life cycle of G. lamblia (CDC, 2024).

Some trophozoites then enter the colon where they are re-encystated in the presence of neutral pH and bile salts (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Encystation occurs when the parasite moves into the large intestine. Cysts are the most common stage found in non-diarrheal stools (CDC, 2024). The encystation process begins with the appearance of encystation specific secretory vesicles (ESVs) within the trophozoite cytoplasm, followed by cyst wall production within 15 hours (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Extracellular vesicles (EVs) of Giardia duodenalis can modify the behavior of enterobacteria through mechanisms involving RNA, namely increasing bacterial motility and enhancing bacterial adhesion/invasion to intestinal epithelial cells (Siddiq et al., 2023).

Within 24 hours of ESV emergence, trophozoites are covered by these cyst wall proteins, resulting in cyst formation. Cyst formation begins with shortening of the flagella followed by condensation of the cytoplasm and finally secretion of a thick hyaline cyst wall (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). These encysted trophozoites then undergo a nuclear division phase and produce quadrinucleated adult cysts. The cysts, which are the infective form of the parasite, are excreted in the feces and the life cycle is repeated (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Since cysts can be contagious when excreted through feces or shortly after, person-to-person transmission can occur (CDC, 2024).

5. Pathogenesis of giardiasis

The infection disrupts the normal absorption function of the small intestine, leading to osmotic overload of the colon resulting in watery diarrhea. Physically attached parasites can envelop the small intestinal mucosa significantly reducing the surface area for absorption. Some parasite molecular products can have chemical effects on mucosal cells. Infection appears to damage and increase the rate of epithelial cell turnover leading to villous atrophy which further reduces the surface area for absorption. These factors contribute to malabsorption of fats and other nutrients resulting in watery diarrhea and steatorrhea accompanied by dehydration, intestinal pain and abdominal distention. Most clinical infections are self-limiting and resolve spontaneously, but some infections persist to cause chronic weight loss, stunted growth, and "failure-to-thrive" syndrome (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019).

6. Immunopathophysiology of giardiasis

Trophozoites, the vegetative form of Giardia, are attached to the intestinal wall using a ventral disk, which can cause damage to the intestinal epithelium. Giardia can affect the integrity of epithelial cell junctions, which contributes to gastrointestinal symptoms. Proteases secreted by Giardia play a role in damaging epithelial cell junctions. The impact of Giardia infection on the immune response and how this can lead to varied gastrointestinal symptoms (Adam, 2021).

Giardia trophozoites adhere to the wall of the small intestine using a structure called the ventral disk. This process allows Giardia to survive in the harsh intestinal environment and disrupt the normal function of the intestinal epithelium. When Giardia was attached, the trophozoites could damage the intestinal epithelial cells, which function to maintain the integrity of the intestinal lining. This damage could cause leaky gut, increase intestinal permeability, and trigger an immune response (Adam, 2021).

a. Innate Immune Response

Recognition by Immune Cells: Immune cells such as macrophages and dendritic cells recognize Giardia through pattern recognition receptors (PRRs) that detect pathogenic components. This triggers the activation of immune cells and the production of cytokines. Pro-inflammatory Cytokine Production: Activated immune cells release pro-inflammatory cytokines such as IL-6, IL-12, and TNF-α. These cytokines serve to recruit more immune cells to the site of infection and enhance the inflammatory response (Adam, 2021).

b. Adaptive Immune Response

The adaptive immune response begins with T cell activation. Activated dendritic cells present Giardia antigens to T cells in lymph nodes, leading to T cell proliferation and differentiation. The immune response to Giardia involves both Th1 and Th2 pathways. T helper 1 (Th1) cells produce cytokines that support cellular responses, while T helper 2 (Th2) cells produce cytokines that support humoral responses. T helper 17 (Th17) cells play an important role in the immune response to

Giardia. IL-17A produced by Th17 contributes to neutrophil recruitment and the production of IgA antibodies, which are important for fighting infection (Adam, 2021).

c. Antibody Production

Giardia infection triggers the production of antibodies, mainly IgA, which serves to protect the intestinal mucosa. IgA can bind to Giardia and prevent it from adhering to epithelial cells. Giardia has the ability to alter its surface antigens (antigenic variation) through variations in its surface proteins (VSPs). This can evade detection by the immune system, thus complicating parasite elimination (Adam, 2021).

d. Negative Impact on Immune Response

Excessive immune response can cause further tissue damage and worsen symptoms. For example, increased production of pro-inflammatory cytokines can lead to chronic inflammation and damage to the intestinal epithelium. Giardia can induce immune tolerance, leading to a decreased immune response to other infections or concurrent pathogens. This may result in recurrent or more severe infections (Adam, 2021).

e. Interaction with Intestinal Microbiota

Giardia infection can alter the composition of the gut microbiota, contributing to dysbiosis. These changes can affect the immune response and increase susceptibility to other infections. Giardia can affect the production of antimicrobial peptides by epithelial cells, which serve to protect the gut from other pathogens (Adam, 2021).

7. Clinical Symptoms and Disease Manifestations

Giardia duodenalis infects the small intestine and can cause a wide range of symptoms, from asymptomatic cases to severe symptoms with acute or chronic conditions (Adam, 2021) (Lafarga-Molina, et al., 2025) (Barasa, Indusa, & Were, 2025). Not all infected individuals show clinical signs, but may remain asymptomatic carriers (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019).

Common symptoms include diarrhoea, abdominal cramps/pain, abdominal, bloating, nausea, and vomiting and dehydration (Barasa, Indusa, & Were, 2025) (CDC, 2024). Commonly reported symptoms included abdominal colic (42.1%) and diarrhoea (13.6%) (Hassanein, Masoud, Awwad, Abdel-Salam, & Shehata, 2023). In chronic giardiasis, symptoms will recur and malabsorption and debilitation may occur (CDC, 2024). Additional symptoms of giardiasis are fatigue and weakness, decreased appetite (Ali, Parkash, Mangrio, & Shaikh, 2025).

The most common symptom of giardiasis is persistent watery diarrhoea lasting more than six days. In this study, 130 of the 133 children involved had diarrhoea, with 15 of them having diarrhoea for 6-10 days. A typical symptom of giardiasis is steatorrhea, a condition in which the stools contain undigested fat, which can cause the stools to be pale in colour and have an unpleasant odour. Most of the infected children had a stool frequency of 1-4 times per day, indicating that giardiasis can cause irregular and recurrent diarrhoea. Another significant symptom was the presence of blood and mucus in faeces, which was detected in 14 children (78.6%) who were positive for giardiasis (Ali, Parkash, Mangrio, & Shaikh, 2025).

Acute giardiasis develops after an incubation period of 1 to 14 days (average 7 days) and usually lasts for 1 to 3 weeks (CDC, 2024). The study showed that diarrhoea duration and faecal frequency were closely related to giardiasis infection status, with children who experienced longer and more frequent diarrhoea more likely to be giardiasis positive (Ali, Parkash, Mangrio, & Shaikh, 2025).

A rare manifestation of giardiasis can cause protein-losing enteropathy (PLE) which is usually undetectable in immunocompetent individuals (Patro, Sharma, Goyal, Panigrahi, & Pattnaik, 2025).

8. Diagnosis of Giardiasis

Routine laboratory tests, including complete blood tests and electrolyte levels, usually give results that tend to be normal in cases of giardiasis. Eosinophilia is a rare finding (Dunn & Juergens, 2024). Cysts can be detected by routine faecal examination (stained smears (wet mount or trichrome staining), or sedimentation/flotation concentration techniques) but test sensitivity is poor due to intermittent cyst excretion (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Detecting Giardia through microscopy can be challenging as the protozoa are only shed intermittently. Microscope sensitivity can be improved by collecting 3 stool samples on different days (Dunn & Juergens, 2024). Endoscopic techniques (gastroscopy to duodenum) have been used in chronic cases to detect trophozoites in intestinal biopsy material (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019).

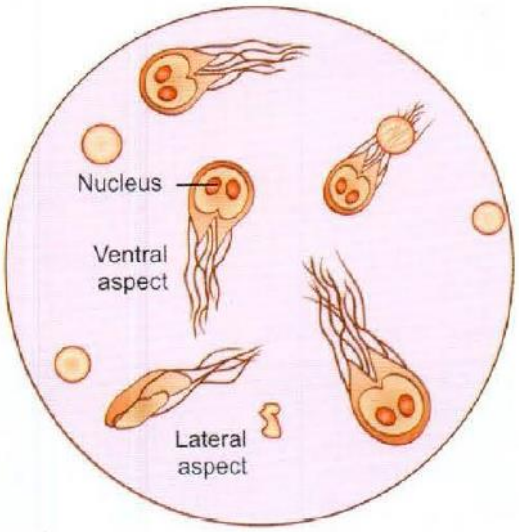


Figure 6. Giardia Lamblia in duodenal fluid wet preparation (1500x magnification) (Ghosh, 2018).

Recently, sensitive and specific immunological techniques have been developed to detect parasite antigens in faecal preparations (coproantigen tests). Similar monoclonal antibody immunoreagents are also used in many countries to detect cysts in water samples using immunomagnetic separation techniques (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Stool antigen enzyme-linked immunosorbent assays are also available. These tests are useful for screening in high incidence situations, such as during epidemics or in daycare centres. However, they cannot replace faecal microscopy (Dunn & Juergens, 2024).

Enzyme immunoassay (EIA) does not rely on microscopy and is useful for screening large quantities of specimens. The borderline positive and doubtful negative results obtained by this technique should be further confirmed by DFA. Giardia antigens are detected in faeces using this method; therefore, specimens should not be concentrated prior to testing**.** The direct fluorescent antibody (DFA) assay is a technique that offers the highest combination of sensitivity and specificity and is considered the gold standard by many laboratories (CDC, 2024)**.**

Rapid immunochromatographic cartridges can be used with preserved specimens and are quick and easy to perform. Giardia antigen is detected in faeces using this method; therefore, specimens should not be concentrated prior to testing. The borderline positive and doubtful negative results obtained by this technique should be further confirmed by DFA (CDC, 2024). However, there are more objective techniques that are now widely used, such as nucleic acid amplification techniques (NAAT). Faecal antigen detection tests

and NAAT are usually faster, more sensitive and more specific than microscopy (Dunn & Juergens, 2024).

Polymerase Chain Reaction (PCR) techniques can identify Giardia in faecal samples, even at low concentrations such as 10 parasites/100 microlitres. PCR can also help screen water supplies for the presence of the parasite. Real-time PCR is effective in detecting mild and asymptomatic infections (Dunn & Juergens, 2024).

Treatment and Management of Giardiasis

1. Available treatments for Giardia infection

Generally, asymptomatic individuals do not require treatment, except in cases where it is necessary to prevent household transmission, especially from infants to pregnant women or patients with cystic fibrosis. Treatment is also recommended for patients with malabsorption associated with G intestinalis who require oral antibiotics for other infections (Dunn & Juergens., 2024).

Standard treatment for giardiasis involves antibiotic therapy, with metronidazole as the first-line treatment for giardiasis. The standard dose for metronidazole is as follows 250 to 500 mg 3 times a day for 5 to 10 days (Dunn & Juergens., 2024). Metronidazole is safe for children, and the common dose is 30 mg/kg to 50 mg/kg per day divided into 3 doses. It is recommended to treat developmentally delayed children with acute or chronic diarrhoea, malabsorption, or other gastrointestinal symptoms when Giardia organisms have been identified (Dunn & Juergens., 2024). Metronidazole is the drug of choice for giardiasis and has mild side effects (such as nausea). However, metronidazole-resistant strains of Giardia have been reported (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Metronidazole has challenges that include a significant failure rate in clearing protozoa from the gut and issues related to patient compliance with taking the medication as recommended by the doctor (Dunn & Juergens, 2024).

Reports of resistance to standard treatments such as the usually effective metronidazole are increasing. Patients experience chronic symptoms such as watery diarrhoea, abdominal pain and significant weight loss despite multiple treatments. Combination therapy of metronidazole and albendazole showed effectiveness in overcoming resistant giardiasis. The dose of metronidazole given is 500 mg orally three times a day (tid) for 3 weeks plus Albendazole with the dose given is 400 mg orally twice a day (bid) for 3 weeks (Atnafu, Usman, Azerefegne, & Shemsu, 2025).

Alternative treatment regimens for giardiasis include tinidazole, nitazoxanide, mebendazole, albendazole, and paromomycin. Paromomycin, which has poor systemic absorption, may be considered for pregnant patients during the first trimester (Connor & Leung, 2025) (Dunn & Juergens., 2024). Other nitroimidazole derivatives (tinidazole), nitrofurans (furazolidones), acridine drugs (quinacrine) and microtubule-inhibiting anthelmintics (albendazole) have been reported to be effective (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). In addition, an increased incidence of nitroimidazole-resistant infections has been reported, especially among travellers from India and other Asian countries (Dunn & Juergens., 2024).

Most patients presenting with giardiasis are non-toxic and may only require oral rehydration for initial fluid resuscitation. In severe cases, intravenous (IV) fluids may be required. Proper fluid and electrolyte management is essential, especially in large fluid losses due to diarrhoea (Dunn & Juergens., 2024). The decrease in incidents in many regions is due to improvements in food hygiene and travelling conditions (Hommes, Dörre, Behnke, Stark, & Faber, 2023)

2. The Impact of Giardia Infection on the Health of Swimming Athletes

a. The effect of giardiasis on the performance of swimming athletes

Giardia infection and other parasites have a high prevalence among young swimmers, which can affect their health and performance. Giardia infection is associated with a decrease in biomarkers important for stamina and endurance, which negatively impacts swimming performance. Decreased biomarkers such as ferritin, transferrin and iron, which negatively impact swimming performance. Research shows that infected swimmers should stop training, which may result in a decline in performance (Hassanein, Masoud, Awwad, Abdel-Salam, & Shehata, 2023).

b. Hygiene and Prevention of Giardia Infection in Swimming Pools

Research emphasises the importance of hygiene awareness and health education to prevent infections in swimming pools (Hassanein, Masoud, Awwad, Abdel-Salam, & Shehata, 2023). Prevention tools for giardiasis infection include hand washing and avoiding exposure to (especially ingestion of) contaminated water (Delamare, Septfons, Alfandari, & Mailles, 2024). Importance of monitoring pool water quality to prevent infection (Pineda, et al., 2020). Control relies heavily on good sanitation, proper waste disposal, and effective water treatment (well-maintained sand filtration or microfiltration, optimal chlorination or ozonation) (Dmitrieva, Kozlov, Sapozhnikov, & Moskovskaya, 2019). Swimming pool hygiene to prevent infection is very important (Schets, Engels, & Evers, 2004).

Increasing awareness of the risk of infection associated with freshwater sports is essential so as to encourage better monitoring of water quality and implementation of preventive measures by freshwater sports organisers (Delamare *et al.*, 2024). Regular health checks and education programmes to raise awareness about infection prevention (Hassanein, Masoud, Awwad, Abdel-Salam, & Shehata, 2023). Participants are provided with health education about the potential for infection and take appropriate preventive measures, such as seeking medical advice if symptoms appear after exposure (Delamare *et al.*, 2024). More awareness raising and wider screening for giardiasis in populations without a history of travel is needed (Krumrie, et al., 2022).

CONCLUSION

In conclusion, the research underscores the critical role of hygiene awareness and health education in preventing infections in swimming pools and freshwater sports. Effective prevention strategies, including hand washing, monitoring water quality, and maintaining proper sanitation, are essential to mitigate the risk of infections such as giardiasis. It is imperative to enhance awareness among participants and organizers about the potential health risks associated with freshwater activities, alongside implementing regular health checks and educational programs. Furthermore, increased screening for giardiasis in populations without travel history is necessary to ensure comprehensive infection prevention and control.

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CONFLICT OF INTEREST

None of the authors have a commercial relationship or financial conflict of interest as part of this study.

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